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WATER QUALITY EVALUATION

FOR THE

LAKE ALERT STUDY

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SUMMARY AND CONCLUSIONS

Basic limnological data for ten selected lakes in the Lake Alert Study area are described in relation to trophic conditions. The extreme vulnerability of Beaver, Loon Call, North Rathbun and Cold Lakes to artificial inputs of nutrients is emphasized.

A water quality ranking system is proposed in which high quality is equated with low productivity and suitability for most water-oriented recreational activities, including an absence of conditions detrimental to fish populations. Parameters included in the ranking are mean depth, water clarity, chlorophyll *a*, the type of distribution of dissolved oxygen in the mid-summer, the Fe:P ratios in the hypolimnion under anaerobic conditions and a morpho-edaphic index. High ranking water quality lakes were Gold, Anstruther, Mississagua, Catchacoma and Rathbun while lower ranking lakes were Wolf, Beaver, North Rathbun, Loon Call and Cold.

INTRODUCTION

General

The Lake Alert Study carried out by Hough, Stansbury and Associates Limited, Landscape Architects and Site Planners, at the request of the Ministry of Natural Resources (formerly the Department of Lands and Forests) was designed to determine a lake's optimum density for cottage development. The study centered on a peripheral portion of the Mississagua River Watershed north of Peterborough and the Buckhorn Wilderness Area. Phase 1 of the investigation (Lake Alert Phase One Report, 1971) included a documentation of available data and an indication of additional needs to ensure the development of an ecologically sound system to categorize lake-shoreline cottaging capacity. As part of "additional needs" personnel of the Biology Section, Ministry of the Environment (formally a Branch within the Ontario Water Resources Commission) were requested to provide a water quality ranking or classification for selected lakes in the study area which would take cognizance of their existing trophic status and would clarify their ability to withstand future changes from development schemes. Finally, the ranking system was extended to permit its use by water management personnel for all lakes in the Precambrian Shield of the Province.

Lake ranking rationale

The most esteemed lakes for recreational development in Ontario are the deep, cold-water highly transparent lakes of the Precambrian Shield, such as the Muskoka Lakes, lakes of the Haliburton Highland region and Lake Temagami. Lakes having these characteristics are termed oligotrophic and are characterized by their low productivity and minimal concentrations of nutrients.

The water quality ranking presented herein was developed as an alternative to the classical, rather lengthy discussions used in past reports (Michalski and Robinson 1970, 1971 and 1972) to delineate the extent of eutrophication in lakes located in the Precambrian Shield. For purposes of our system, high quality was equated with low biological activity and suitability for most water-oriented recreational activities, including the absence of conditions detrimental to cold-water fish populations. Low quality was associated with indications of high biological activity and conditions not conducive to most water-oriented recreational activities. The ranking was designed to take cognizance of a number of significant physical, chemical and biological features. Of some importance is that each parameter (presented in Table 1 in relation to high-water quality as defined above) can be easily obtained at minimum expense. Additionally, the parameters chosen are important to water quality assessments, not only for documenting the vulnerability of a lake (i.e. dissolved oxygen distribution and Fe:P ratios in the bottom waters), but from a public (water clarity and chlorophyll levels) and fisheries (morpho-edaphic index*) point of view. The ranking scheme is sufficiently flexible to permit incorporation of other features including water temperature, the ratio of the euphotic zone to hypolimnion, shoreline development and bacterial conditions - depending upon the availability of manpower and finances.

* The morpho-edaphic index used was that developed by Ryder (1965) for north-temperate lakes (i.e. a ratio of the total dissolved solids to mean depth; the ratio can be used as a means of estimating the potential productivity of a lake).

Table 1: Parameters used in ranking of lakes located in Ontario's Precambrian Shield. The parameters are presented in reference to their relation to high-water quality as defined in the text.

Parameter	Relation to high-water quality
Mean Depth	direct
Secchi disc depth	direct
Chlorophyll _a_	inverse
Oxygen distribution in the mid-summer	direct
Morpho-edaphic index	inverse
Fe to P ratio in the hypolimnion under anaerobic conditions	direct

It is recognized that the scheme has several limitations. Purely from a fisheries production viewpoint, eutrophic or productive lakes could be considered high quality while the rationale utilized herein would cause such waters to be classified as low quality. Additionally, conditions have developed in certain lakes in the Pre-cambrian Shield to retard further the low biological activity of oligotrophic lakes. The condition has led, in many cases, to the complete loss of lake trout fisheries (see Conroy 1971 and Sudbury Environmental Task Force 1971). These lakes would rate high in the proposed ranking system although degraded water quality is apparent. It is important at this point in time to consider the proposal as "open" in the sense of Schlesinger (1963), i.e. an idea that will not be proven or disproven in one test, but one which must be subjected to continuous revisions and re-statements as better information becomes available (reproduced from Schindler 1971).

METHODS

Information on lake morphometry and dissolved oxygen and temperature regimes for lakes Gold, Catchacoma, North Rathbun, Rathbun, Mississagua, Wolf, Cold, Anstruther, Loon Call and Beaver were acquired from the Ministry of Natural Resources Lake Survey Summary Sheets.

Between June 23 and September 15, 1971 personnel of the Ministry of Natural Resources visited each lake on a weekly basis. Secchi disc readings were recorded at one or two representative deep-water sampling locations per lake to evaluate water clarity. Thirty-two ounce composite samples for concentrations of chlorophyll were taken at the same stations where water clarity readings were made through the euphotic zone i.e. zone of significant light penetration measured as twice the Secchi disc depth.

These samples were preserved with 1ml of 2% magnesium carbonate and were delivered to the mobile laboratory located on the campus at Trent University, Peterborough, where 300-1,000mls of each sample were filtered under vacuum using a 1.2μ millipore filter and were refrigerated in plastic containers for shipment to Toronto.

During the middle of August, samples from the euphotic zone and strata of water 1m above bottom were taken at each of the main lake stations by staff of the Ministry of Natural Resources for analyses of concentrations of total phosphorus (as mg/l P), total Kjeldahl, free ammonia, nitrate and nitrite nitrogen (as mg/l N) and total iron (as mg/l Fe). Collections for Cold and Catchacoma Lakes were taken by personnel of the Ministry of the Environment.

Data for mean depth, Secchi disc as a function of depth, chlorophyll a concentrations, the type of dissolved oxygen distribution in the mid-summer, the iron-phosphorus ratio under anaerobic conditions at 1m above bottom and the morpho-edaphic index were used to establish a water quality ranking among the lakes. In order to develop the rank, a rating scale of 10 was adopted. The absolute range for each parameter was therefore limited to 0-10. For each parameter the lake having the best water quality was given the highest rank (10); conversely, the lowest rank (0) for the same parameter was given to the lake having the poorest water quality. For example, the highest and lowest mean Secchi disc readings were recorded from Anstruther and Cold Lakes, respectively. Corresponding water quality ranking values were 10 and 0. Proportionate ratings for those lakes having values between the minimum and maximum for all lakes were computed following the suggestion of Fredin and Larder as quoted by Reimers et al. (1955).

$$\text{Rank for a lake} = \frac{10\ (X - Y)}{Z - Y} \quad \text{where,}$$

X is the value for a given lake,

Y is the minimum value for all lakes and

Z is the maximum value for all lakes.

For parameters related inversely to water quality (for example, chlorophyll a), the equation was revised to:

$$\text{Rank for a lake} = \frac{10\ (Z - X)}{Z - Y}$$

Various dissolved oxygen distributions (for example, orthograde or non-diminishing with depth) were assigned a value between 1 and 7;* proportionate ratings between 0 and 10 for these values were determined following the aforementioned procedure. The water quality ranking system described, places all factors on a common scale and allows for the objective placement of intermediate ranking lakes in proportion to absolute values. Rank values for each lake may then be averaged; this average would not be weighted by variations in absolute ranges among the parameters.

* Values for types of oxygen distribution were subjectively applied as follows:

Orthograde - 7. Oxygen concentrations are non-diminishing with depth.

Clinograde - 3. Oxygen concentrations diminish with depth.

Positive or negative heterograde - 3. Increases or decreases in oxygen concentrations in the thermocline or upper hypolimnial regions.

Anaerobic conditions at 1m above bottom - 1.

RESULTS

Data on lake morphometry, water clarity and numbers of cottages are provided in Table 2.

Temperature and dissolved oxygen profiles for each lake are depicted in Figure 1. As illustrated, well-defined thermoclines (probably second order lakes of Hutchinson, 1957) or zones of rapid temperature decreases characterized all lakes with the exception of Wolf which was thermally homogenous (a third order lake of Hutchinson, 1957) at the time of sampling.

Clinograde oxygen distributions or reductions in oxygen concentrations in the deeper layers of Beaver, Loon Call, North Rathbun and Cold Lakes were evident. Orthograde or non-diminishing distributions were recorded from Rathbun, Gold, Anstruther, Mississagua, Catchacoma and Wolf Lakes. (The authors assume that oxygen regimes below 25-30m for the five deep lakes are orthograde.) A slight indication of a positive heterograde oxygen distribution or metalimnetic maximum occurred in Loon Call Lake.

Data on chemical conditions in the euphotic zone and at 1m above bottom in the lakes are presented in Table 3. In the thermally stratified lakes, concentrations of total phosphorus, total Kjeldahl and nitrate nitrogen, silica and iron were usually higher in the hypolimnia than in the upper strata. Concentrations of free ammonia and nitrite nitrogen were generally uniform with depth for all lakes. In Wolf Lake, the only lake where thermal stratification did not materialize, nutrient conditions were either slightly lower in the deeper strata than in the surface waters or uniform with depth. Generally, absolute concentrations of phosphorus and nitrogen in the surface waters were low and would not be expected to produce excessive algal and/or plant growths.

Table 2: Information on lake morphometry, water clarity and numbers of cottages on selected lakes in the Lake Alert Study area.

Lake	Maximum depth (m)	Mean depth (m)	Lake area (km^2)	Lake volume (m^3)	Secchi disc (m)		Number of Cottages
					Range	Mean	
Beaver	18.3	7.1	1.42	9.20×10^6	4.1-5.3	4.6	131
Loon Call	17.0	5.4	0.86	4.31×10^6	3.5-5.5	4.5	81
Wolf	9.1	5.0	1.25	5.83×10^6	2.9-4.7	3.5	56
North Rathbun	13.4	4.7	0.28	1.24×10^6	2.9-4.9	3.7	1
Rathbun	42.0	13.1	1.12	13.47×10^6	3.8-6.4	5.0	2
Cold	7.6	2.1	0.92	2.43×10^6	2.9-4.0	3.4	1
Catchacoma	43.8	21.5	6.87	139.66×10^6	4.0-6.4	4.7	210
Anstruther	39.6	16.2	6.24	93.17×10^6	4.3-7.3	5.7	251
Mississagua	39.6	19.4	5.87	103.96×10^6	4.3-8.6	5.0	217
Gold	39.6	26.6	3.12	71.33×10^6	4.1-7.1	5.1	151

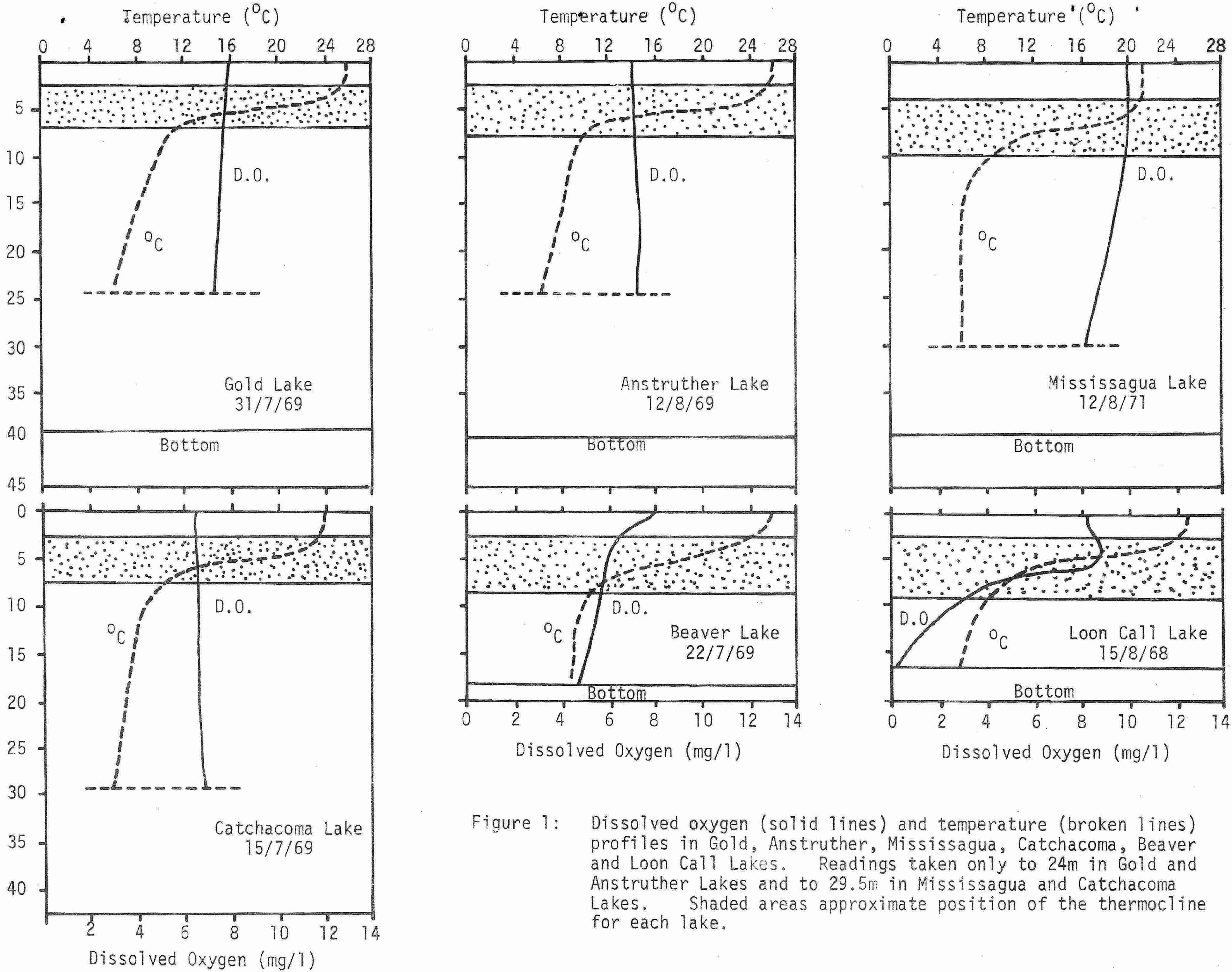

Figure 1: Dissolved oxygen (solid lines) and temperature (broken lines) profiles in Gold, Anstruther, Mississagua, Catchacoma, Beaver and Loon Call Lakes. Readings taken only to 24m in Gold and Anstruther Lakes and to 29.5m in Mississagua and Catchacoma Lakes. Shaded areas approximate position of the thermocline for each lake.

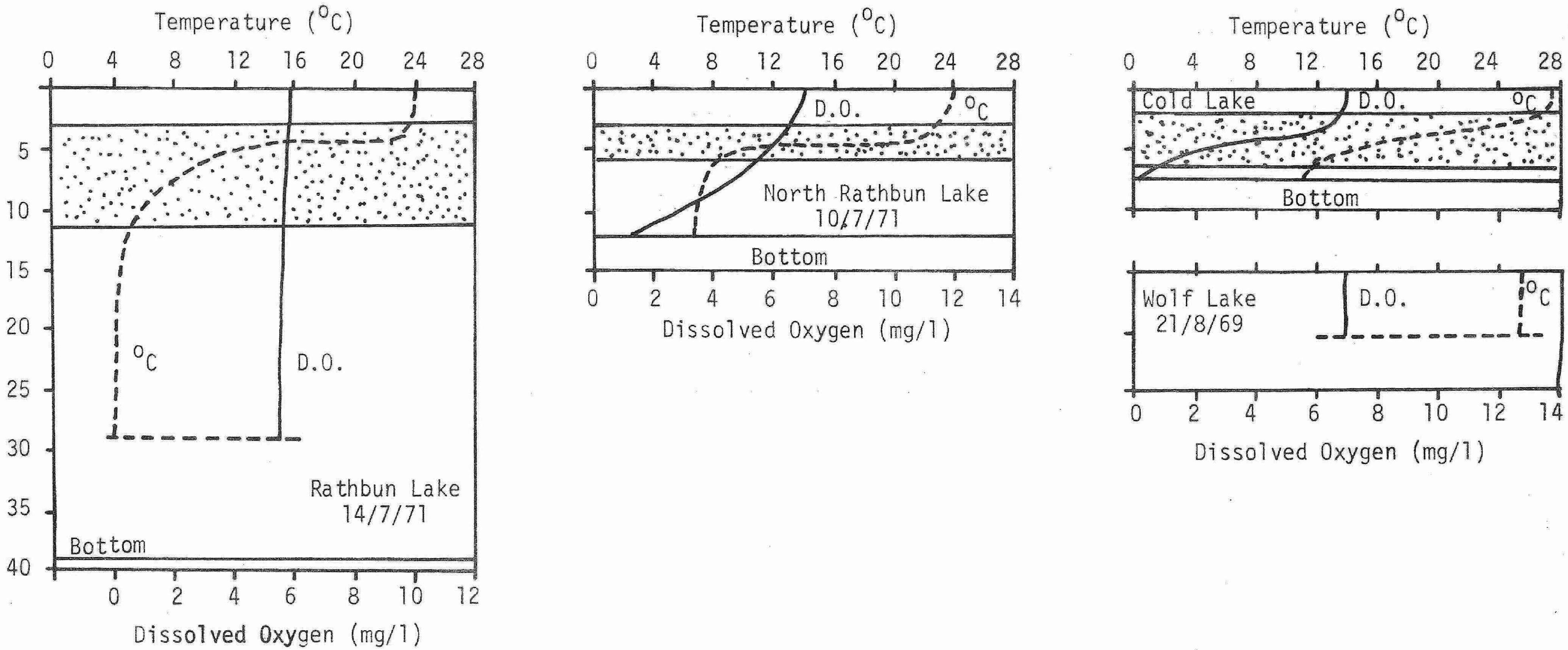

Figure 1: (continued) Dissolved oxygen (solid line) and temperature (broken line) profiles in Rathbun, North Rathbun, Cold and Wolf Lakes. Readings taken only to 28.5m in Rathbun Lake and to 6.0m in Wolf Lake. Shaded areas approximate the position of the thermocline for each lake.

Table 3: Concentrations of total phosphorus, total Kjeldahl, free ammonia, nitrate and nitrite nitrogen, silica and iron in the euphotic zone and at 1m above bottom in selected lakes in the Lake Alert Study area. The iron phosphorus ratios are from samples taken 1m off bottom while total dissolved solids are reproduced from Ministry of Natural Resources Lake Survey Sheets.

Lake		Total Phosphorus (mg/l)	Nitrogen (mg/l)				Silica (mg/l)	Iron (mg/l)	Fe/P	Total Diss. Solids (mg/l)
			T.K.N.	Free Ammonia	Nitrate	Nitrite				
Beaver	(e)	.014	.26	.02	.06	.004	2.90	.10	14.0	22.0
	(b)	.045	.44	.05	.24	.007	4.50	.63		
Loon Call	(e)	.012	.26	.02	.03	.005	0.60	.15	9.2	38.0
	(b)	.038	.38	.02	.06	.006	0.80	.35		
Wolf	(e)	.018	.37	.05	<.01	<.003	0.60	.15	-	32.0
	(b)	.016	.30	.03	.03	.004	0.60	.16		
North Rathbun	(e)	.017	.35	.04	.01	.006	1.40	.30	30.5	13.0
	(b)	.018	.43	.01	.02	.008	1.60	.55		
Rathbun[1]	(e)	-	-	-	-	-	-	-	-	33.6
	(b)	-	-	-	-	-	-	-		
Cold	(e)	.015	.42	.03	.02	.004	2.50	.26	34.7	20.0
	(b)	.017	.49	.06	.05	.006	3.70	.59		
Catchacoma	(e)	.013	.45	.07	.11	.006	2.50	.05	-	29.0
	(b)	.010	.30	.02	.22	.004	3.60	.20		
Anstruther	(e)	.018	.31	.01	.20	.004	1.00	.05	-	25.1
	(b)	.018	.28	.02	.22	.002	2.80	.16		
Mississagua	(e)	.014	.29	.01	.10	.004	2.60	.05	-	28.8
	(b)	.016	.38	.05	.21	.004	3.40	.16		
Gold	(e)	.012	.22	.02	.07	.004	2.60	.05	-	23.0
	(b)	.022	.29	.04	.19	.005	3.40	.25		

e - euphotic zone sample; b - bottom sample; [1] - chemical data not available.

Chlorophyll a concentrations are presented in Table 4. Levels ranged from a low of 0.3 μgm/l for Catchacoma Lake to a high of 13.1 μgm/l for Cold Lake.

DISCUSSION

Trophic status of lakes

Depending upon the degree of plant nutrient enrichment and resulting biological productivity, lakes of north temperate regions as well as many tropical lakes have been classified into three intergrading types, oligotrophic, mesotrophic and eutrophic. Oligotrophic lakes are poorly supplied with plant nutrients and support little plant growth. As a result, these lakes are generally deep, clear and unproductive with the deeper water well-supplied with oxygen throughout the year. Such lakes can support cold-water species of fish such as lake trout, whitefish and herring. Eutrophic lakes on the other hand, are richly supplied with plant nutrients and support heavy plant growths. The deeper waters of such lakes become depleted in oxygen owing to decomposition of the abundant material produced. Eutrophic lakes are turbid, warm, productive and contain game fish species such as walleye, pike and perch. Lakes of intermediate types are termed mesotrophic; that is, they have a moderate supply of nutrients, plant growths and biological production. Often these lakes contain both warm and cold-water species of fish.

Mean Secchi disc values ranging between 3.4 and 5.7m in the study area were somewhat less than corresponding recordings from oligotrophic lakes Kukagami (12.0, Conroy 1971), Joseph (8.1m, unpublished Ministry of the Environment data) and Rosseau (6.1m, unpublished Ministry of the Environment data), yet greater than those obtained for Gravenhurst Bay (1.6m, unpublished Ministry of the Environment data and Riley Lake (1.7,m Michalski and Robinson 1970), both of which are considered to be in an

Table 4: Summary of chlorophyll a (μgm/l) collected from selected lakes in the Lake Alert Study area.

Lake	Number of Analyses	Chlorophyll a Maximum	Chlorophyll a Minimum	Chlorophyll a Mean
Beaver	10	4.1	0.7	2.7
Loon Call	11	2.4	0.7	1.5
Wolf	11	3.6	0.9	2.3
North Rathbun	11	6.4	1.4	4.4
Rathbun	11	3.5	0.7	2.1
Cold	11	13.1	2.4	5.4
Catchacoma	20	2.8	0.3	1.2
Anstruther	21	2.1	0.6	1.3
Mississagua	19	2.0	0.6	1.2
Gold	11	3.2	0.6	1.9

advanced state of eutrophication. Vallentyne (1969) has indicated that lakes having Secchi disc readings below 3m are eutrophic in nature while those exceeding 6m are oligotrophic in status. On the basis of these guidelines as well as by evaluating the data presented, lakes in the study area would be classified as mesotrophic.

The deep-water oxygen deficits and corresponding clinograde oxygen distributions in Beaver, Loon Call, North Rathbun and Cold Lakes indicate substantial synthesis of nutrients into plant material and its subsequent decomposition at the expense of the oxygen resource in the hypolimnia of the lakes. These oxygen deficits reflect the extreme vulnerability of these lakes to artificial inputs of domestic wastes (Brydges, 1971). The positive heterograde oxygen distribution detected in Loon Call Lake undoubtedly resulted from maximum photosynthesis in the mid-thermocline region. A number of authors including Eberly (1959, 1963 and 1964), Wetzel (1966), Findenegg (1963 and 1964) and Baker et al. (1969) indicated that such dissolved oxygen distribution curves are characteristic of mesotrophic lakes. However, one must be extremely cautious when relating this type of distribution to the trophic condition of many relatively small, well-protected undeveloped lakes in the Precambrian Shield (Schindler 1971, Michalski and Robinson 1969 and Michalski 1971). The high photosynthetic activity in the metalimnion likely resulted from a more favourable nutrient regime (i.e. P, N and CO_2) even though sub-optimal light conditions prevailed. The orthograde curves of Rathbun, Gold, Anstruther, Mississauga, Catchacoma and Wolf Lakes suggest oligotrophic water quality conditions.

During thermal stratification, the vertical distribution of nutrients (phosphorus, nitrogen and silica) in lakes located in the Precambrian Shield region of Ontario will vary depending on the degree of shoreline development and deep-water oxygen conditions and the nature of the bottom sediments. For example, only slight variations in nutrient concentrations existed between surface and bottom-waters of lakes having well-oxygenated hypolimnia (i.e. Lakes Mississagua, Catchacoma and Anstruther). On the other hand, nutrient

levels in the hypolimnia of lakes having anaerobic bottom waters and substantial shoreline development (i.e. Lakes Beaver and Loon Call) were substantially higher than those in the upper strata. The presence of relatively high iron concentrations at 1m above bottom in Beaver, Loon Call, Cold and North Rathbun Lakes suggests that phosphorus re-cycling mechanisms may have been operative. Brydges (1971) utilized information from twelve lakes, all of which were thermally stratified and exhibited clinograde oxygen curves and demonstrated that apparently insignificant yearly inputs of phosphorus from septic tank installations and/or other cottage waste disposal systems were instrumental in accelerating eutrophication by becoming incorporated into the lakes' iron-phosphorus re-cylcing mechanisms. The author argued that although inputs in any one year may not be sufficient to create problems, over a number of years conditions of accelerated eutrophy will materialize. It follows therefore, that in a developed lake the amount of phosphorus re-cycling relative to the amount of iron would be expected to be greater than in an undeveloped lake. A comparison of the iron-phosphorus ratios for North Rathbun (30.5) and Cold Lakes (34.7) - two undeveloped lakes exhibiting anaerobic conditions in the deep waters, with those of Beaver (14.0) and Loon Call Lakes (9.2) - two developed lakes having hypolimnetic oxygen deficits, suggests that relatively low yearly inputs of phosphorus from cottagers surrounding the latter lakes are being incorporated into their iron-phosphorus re-cycling mechanisms. Eventually, water quality in Beaver and Loon Call lakes will be undermined unless adequate containment of domestic wastes from surrounding cottages is effected.

Chlorophyll a is the amount of photosynthetic green pigment in algae and its concentrations can be used as an indication of the degree of biological activity in a lake at the time of sampling. Experience has indicated that concentrations between 0 and 5 µgm/l are low and indicate low to moderate algal densities. Concentrations between 5.0 and 10.0 µgm/l, although moderately high, may be considered acceptable for most water-oriented recreational pursuits. Levels between 10 and 15 µgm/l reflect high algal crops.

At these higher levels deterioration of water quality for recreational activities such as swimming and water skiing may be expected, as well as a reduction in aesthetic quality. Vallentyne's (1969) guidelines which indicate that acceptable levels are <5 μgm/l while dangerous concentrations occur above 10 μgm/l are remarkably similar to our established "water-use oriented criteria". As indicated in Table 4, chlorophyll levels in the selected lakes were generally low to moderate reflecting good water quality conditions.

As mentioned above, chlorophyll a is the amount of photosynthetic green pigment in algae while water clarity which is one of the most important parameters used in defining water quality, is determined by means of a Secchi disc. Recently, Brown (1972) has indicated that a near-hyperbolic relationship exists between chlorophyll a concentrations and Secchi disc readings. Figure 2 describes the author's mathematical relationship between chlorophyll a and Secchi disc for 945 sets of data collected from approximately sixty lakes. Points for eutrophic lakes which are characterized by high chlorophyll a concentrations and poor water clarity are situated along the vertical axis of the hyperbola while oligotrophic waters which have low chlorophyll a levels and allow significant light penetration lie along the horizontal limb. Data for mesotrophic lakes would be dispersed about the middle section of the curve. Chlorophyll a and Secchi disc data from the selected lakes in the Lake Alert Study area were positioned in close proximity to oligotrophic lakes Joseph and Huron and were well-removed from the eutrophic waters of Riley Lake, Gravenhurst Bay, the Bay of Quinte and the Western Basin of Lake Erie. Lakes Cold, Wolf and North Rathbun appear slightly more productive than the remaining selected lakes.

Water quality ranking of lakes in the Precambrian Shield

As mentioned earlier, the proposed ranking system equates high quality with low productivity and suitability for most water-oriented recreational activities, including absence of conditions detrimental to cold-water fish

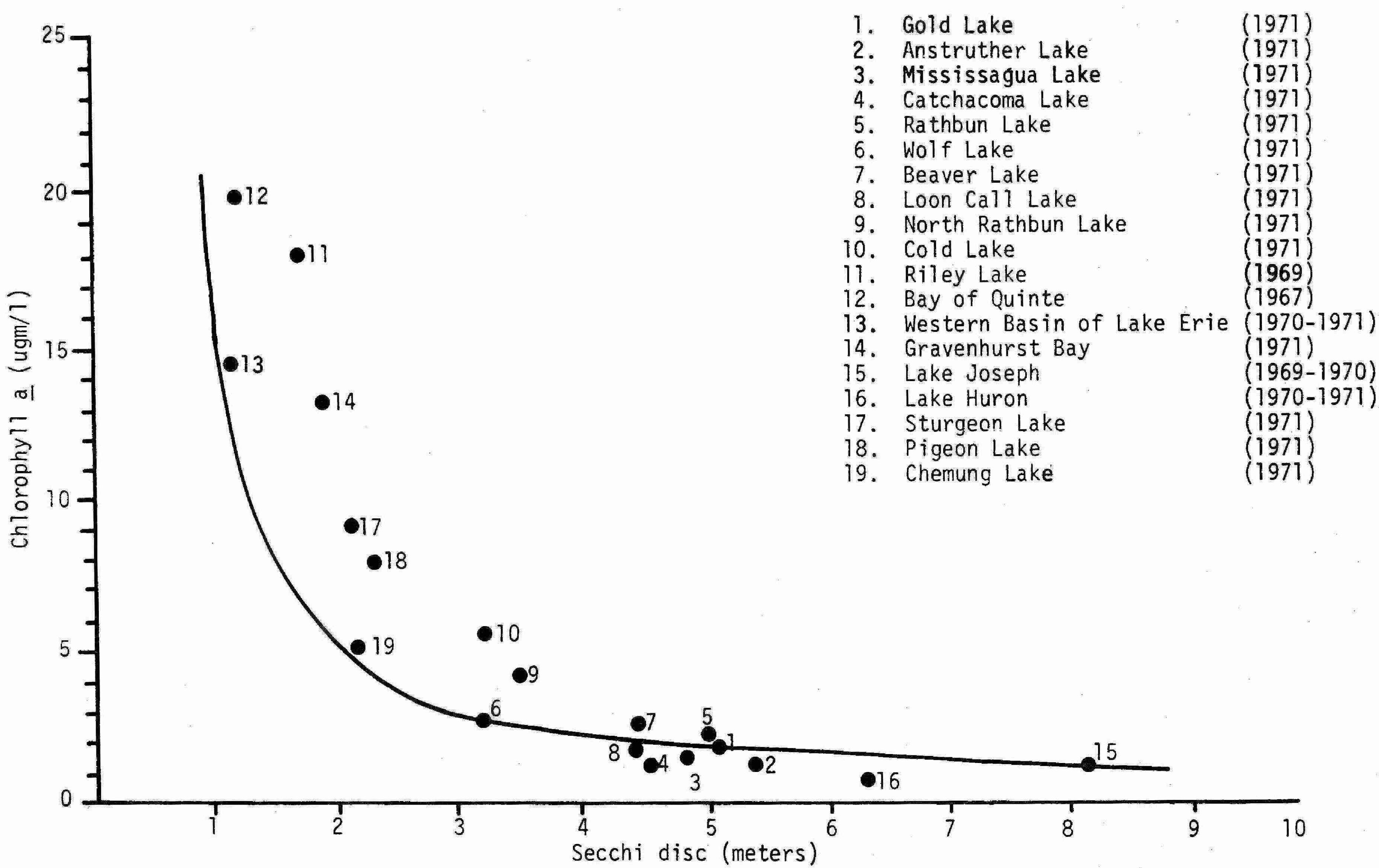

Figure 2: The relationship between chlorophyll a and Secchi disc for ten selected lakes in the Lake Alert study area. Values for each lake are based on mean values collected between June 23 and September 15, 1971. Also, information from a number of other lakes are included as an indication of the relative status of lakes in the Lake Alert area.

populations. The point of view is recognized, however, that lakes may be considered to be high in quality when productive from the fisheries standpoint.

In Table 5, the Lake Alert lakes are arranged in a high-to-low water quality order on the basis of average values derived from each of the measured parameters. As indicated, lakes having the most desirable water quality are the deepest while shallower lakes are characterized by lower water quality rankings.

Because examples of extreme oligotrophy and eutrophy were not available in the Lake Alert Study area, a more realistic approach would be to consider the Lake Alert lakes in a range of lakes covering a broader trophic spectrum (Table 6). A careful examination of the lakes in Table 6, together with the authors' knowledge of the physical, chemical and biological conditions of the lakes reveals three groupings: 1) lakes having a ranking greater than 6, 2) lakes ranking between 3 and 6 and 3) those less than 3. A ranking greater than six reflects excellent water quality, while a rating between 3 and 6 indicates water quality conditions which are vulnerable to artificial waste inputs. Poor water quality conditions can be expected with a ranking of three or less. Although additional lakes may be added to the spectrum, only slight changes in the relative status of those lakes presented in Table 6 should occur as limits on the trophic spectrum should not be drastically altered. Significantly, the five deepest lakes of those selected in the study area were those having excellent water quality. The remaining lakes (i.e. North Rathbun, Beaver, Loon Call, Cold and Wolf) are vulnerable to change.

Assuming the availability of essential data, water management personnel could utilize the proposed system for evaluating any recreational lake by developing proportionate rankings for the parameters included in Table 6 and by assigning a trophic status based on the mean rank.

Table 5: Ranking of ten selected lakes in the Lake Alert Study area according to proportionate ratings of selected parameters.

Lake	PROPORTIONATE RATINGS						Average Rank
	Mean	Secchi disc	Chlorophyll	Oxygen Distribution	Morpho-edaphic	Fe/P	
Gold	10.0	7.4	8.3	10.0	10.0	-	9.1
Anstruther	5.7	10.0	9.7	10.0	9.3	-	8.9
Mississagua	7.1	6.9	10.0	10.0	9.3	-	8.6
Catchacoma	7.9	5.6	10.0	10.0	9.6	-	8.6
Rathbun	4.4	6.9	7.8	3.3	10.0	-	6.4
Wolf Lake	1.1	0.4	7.3	10.0	0.0	-	3.7
Beaver Lake	2.0	5.2	6.4	0.0	5.8	1.8	3.5
North Rathbun	1.0	1.3	2.3	0.0	8.0	8.3	3.4
Loon Call	1.3	4.8	9.2	0.0	9.5	0.0	3.1
Cold	0.0	0.0	0.0	0.0	0.6	10.0	1.7

Table 6: Ranking of twenty-two lakes situated in the Precambrian Shield region of Ontario according to proportionate ratings for selected parameters. Values for each parameter are indicated in brackets.

Lake	PROPORTIONATE RANKING						Average
	Mean Depth	Secchi Disc	Chlorophyll a	Morpho-edaphic index	Fe/P	Oxygen distribution	
Joseph	9.4 (25.3)	10.0 (8.1)	10.0 (1.1)	9.1 (0.5)	- (-)	10.0 (a)	9.7
Rosseau	9.5 (25.5)	7.4 (6.2)	9.6 (1.7)	9.2 (0.5)	- (-)	10.0 (a)	9.1
Gold	10.0 (26.6)	5.3 (5.1)	9.5 (1.9)	10.0 (0.3)	- (-)	10.0 (a)	8.9
Catchacoma	7.9 (21.5)	4.6 (4.7)	9.9 (1.2)	9.5 (0.4)	- (-)	10.0 (a)	8.3
Mississagua	7.0 (19.4)	5.1 (5.0)	9.9 (1.2)	9.4 (0.5)	- (-)	10.0 (a)	8.3
Anstruther	5.7 (16.2)	6.2 (5.7)	9.8 (1.3)	9.3 (0.5)	- (-)	10.0 (a)	8.2
Little Lake Joseph	6.0 (17.0)	6.5 (5.9)	9.2 (2.5)	8.7 (0.7)	- (-)	8.3 (b)	7.7
Muskoka	6.0 (16.8)	4.1 (4.4)	9.5 (1.9)	8.3 (0.8)	- (-)	10.0 (a)	7.5
Rathbun	4.4 (13.1)	5.1 (5.0)	9.4 (2.1)	10.0 (0.3)	- (-)	3.3 (b)	6.4
Skeleton Bay	2.9 (9.4)	5.3 (5.2)	9.7 (1.7)	7.0 (1.2)	- (-)	3.3 (b)	5.5
Walker's	1.0 (4.7)	8.2 (7.0)	8.9 (2.9)	9.4 (0.5)	4.6 (18.0)	0.0 (c)	5.3
Buchanan	1.6 (6.2)	3.0 (3.5)	8.6 (3.5)	8.9 (0.6)	9.4 (33.0)	0.0 (c)	5.2
Dudley Bay	1.8 (6.7)	5.0 (4.9)	9.7 (1.5)	5.8 (1.6)	- (-)	3.3 (b)	5.1
North Rathbun	1.0 (4.7)	3.2 (3.7)	8.0 (4.4)	7.9 (0.9)	8.7 (30.5)	0.0 (c)	4.8
Wolf	1.1 (5.0)	2.8 (3.5)	9.3 (2.3)	0.0 (3.4)	- (-)	10.0 (a)	4.6
Beaver	2.0 (7.1)	4.5 (4.6)	9.0 (2.7)	5.8 (1.6)	3.3 (14.0)	0.0 (c)	4.1
Cold	0.0 (2.1)	2.7 (3.4)	7.5 (5.4)	0.8 (3.1)	10.0 (34.7)	0.0 (c)	3.5
Loon Call	1.3 (5.4)	4.4 (4.5)	9.7 (1.5)	3.5 (2.3)	1.8 (9.2)	0.0 (c)	3.4
Silver	1.5 (6.0)	4.2 (4.4)	7.6 (5.3)	5.3 (1.7)	0.0 (3.5)	0.0 (c)	3.2
Little Panache Lake	2.2 (7.6)	2.2 (3.1)	6.8 (6.5)	5.4 (1.7)	1.1 (7.0)	0.0 (c)	2.8
Gravenhurst Bay	2.0 (7.0)	1.8 (2.7)	5.6 (8.6)	5.2 (1.8)	2.1 (10.1)	0.0 (c)	2.7
Riley	1.5 (5.8)	0.0 (1.6)	0.0 (18.3)	5.1 (1.8)	2.3 (9.0)	0.0 (c)	1.4

a = orthograde: b = clinograde and/or positive and/or negative heterograde: c = anaerobic conditions at 1m above bottom.

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